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Agricultural Research

MSEA Projects Tackle Groundwater Problems

The MSEA Water Quality Research Program

The U.S. Department of Agriculture has been involved in water quality research for three decades, but never with more intensity than right now. The Department supports long-term programs that exploit the capabilities and activities of more USDA agencies—and that work in closer concert with a wider variety of federal and state agencies—than ever before.

In 1990, a long-term, multiagency project focusing on water quality, called the Management Systems Evaluation Area (MSEA, pronounced *mee-sa*) program, was begun. This program includes not only USDA, the U.S. Geological Survey (USGS), and the U.S. Environmental Protection Agency (EPA), but also State agricultural experiment stations, the State Cooperative Extension System, and other state and local agencies.

Within USDA, leadership for the MSEA program is provided by the Agricultural Research Service (ARS) and the Cooperative State Research Service (CSRS), in cooperation with the Soil Conservation Service (SCS), the Extension Service (ES), and the Economic Research Service (ERS). ARS is conducting a major portion of the research on developing better techniques and methods for managing land use, soil, water, nutrients, and pests.

CSRS, often in cooperation with ARS, is encouraging state cooperators to conduct targeted research to address needs for different management systems throughout the Midwest. ARS, CSRS, SCS, and ES are working together to make the results available quickly to other agencies. ERS is coordinating assessments of profitability and social acceptability of various farming systems.

The USGS' Mid-Continent Herbicide Initiative is providing expertise on geology, hydrology, and groundwater movement. EPA, as part of the Midwest Agrichemical Surface/Subsurface Transport and Effects Research project, is leading efforts to assess effects on ecosystems.

MSEA brings together scientists from a variety of public sector and academic settings in an integrated, multiagency program that stresses unity of purpose. The research itself is conducted cooperatively by federal, state, and university scientists; planning, evaluation, and oversight are managed by interagency groups.

The MSEA program evaluates the effect of agricultural management practices and systems on the quality of water resources. MSEA also serves to increase understanding of processes affecting water resource contamination and works to develop cost-effective strategies to reduce water contamination from pesticides and plant nutrients.

Other MSEA research projects augment existing databases and make findings and recommendations available to farmers, scientists, government agencies, industry, and the general public.

MSEA research is presently conducted in eight states, although there are plans to transfer some of the technology nationally. The research program addresses a wide range of surface and subsurface water quality issues. Some examples are:

- Farming systems are customized to regional or local conditions. Unique combinations representing the most appropriate farming systems are evaluated at a variety of sites.
- Different management systems are compared to determine which are most environmentally sound. Water samples in all parts of the hydrological system are analyzed to detect alachlor, atrazine, metribuzin, and other herbicides, as well as carbofuran, nitrate, and phosphorus. These are the most common chemicals used in the production of corn and soybeans in the Midwest.
- Data quality is improved. Rigorous protocols have been developed for collecting samples and recording data. And analyses of all water quality samples within MSEA are independently verified by an external laboratory.
- Models and decision aids enable scientists to better account for processes that take place when water passes through soil. Some of the processes evaluated include: rates of waterflow through macropores, effects of tillage and residue cover on movement of water and chemicals, dynamics of herbicides, nitrogen cycling and transformations, and evaluation of plant and root growth patterns and water uptake patterns.
- Effects on ecosystems are tracked to enable prediction of how agricultural practices affect ecological resources. Information on the fate and transport of agrichemicals in subsurface and surface waters is integrated with information on how agricultural practices affect entire watersheds.
- Socioeconomic factors such as profitability, effects on vendors, convenience, and economic incentives play an important role in the choice of management practices. Farm-level evaluations of modified farming systems are conducted, not only to assess how well they protect surface and groundwater, but also to learn whether they're accepted by farmers in different areas.

The Midwest was chosen as a pilot research area. Why the Midwest? Because it is one of the most intensively farmed areas in the United States, producing more than 80 percent of the corn and more than 70 percent of the soybeans we grow. Such intense agriculture has commanded the use of about 58 percent of U.S. nitrogen fertilizer and almost 60 percent of the herbicides we use.

"Midwest Water Quality Project Matures" in this issue of *Agricultural Research* takes a closer look at what's happening to groundwater on a typical Midwestern farm.

Dale A. Bucks
ARS National Program Leader
for Water Quality Research

Agricultural Research

Cover: **As a part of USDA's water quality program, ARS and cooperating researchers are investigating the effects of farm pesticides and nitrogen from fertilizer on groundwater quality. At an Ohio site near Piketon, ARS soil scientist Norm Fausey (left rear) and U.S. Geological Survey hydrogeologist Martha Jagucki draw water for nutrient and pesticide analysis from a multiport well. Ohio State University graduate students Chris Finton and Abe Springer (foreground) check the elevation of water in a conventional well and download records from a data logger that records hourly information about water temperature, pH, and conductivity.** (K5184-1) Photo by Keith Weller.

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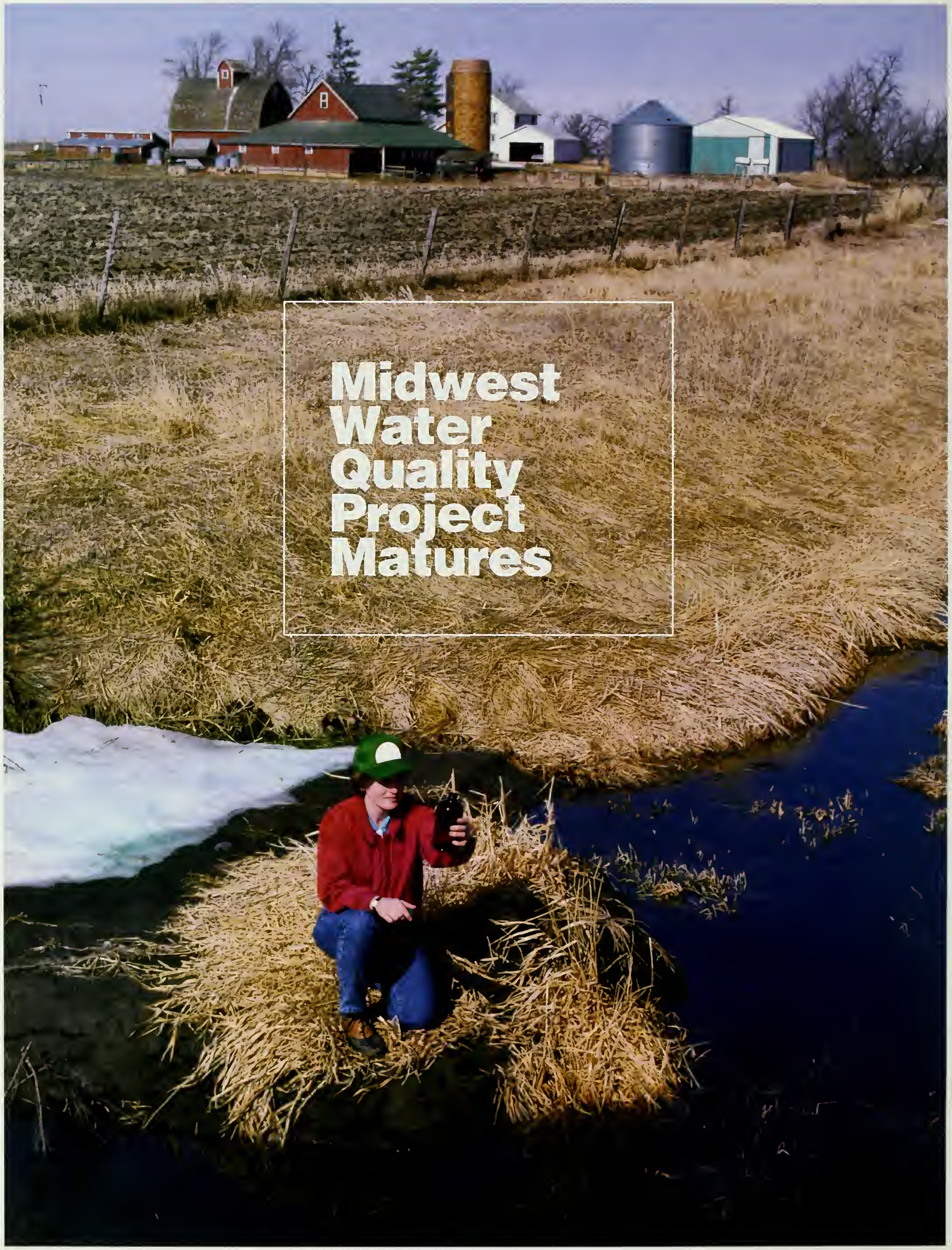
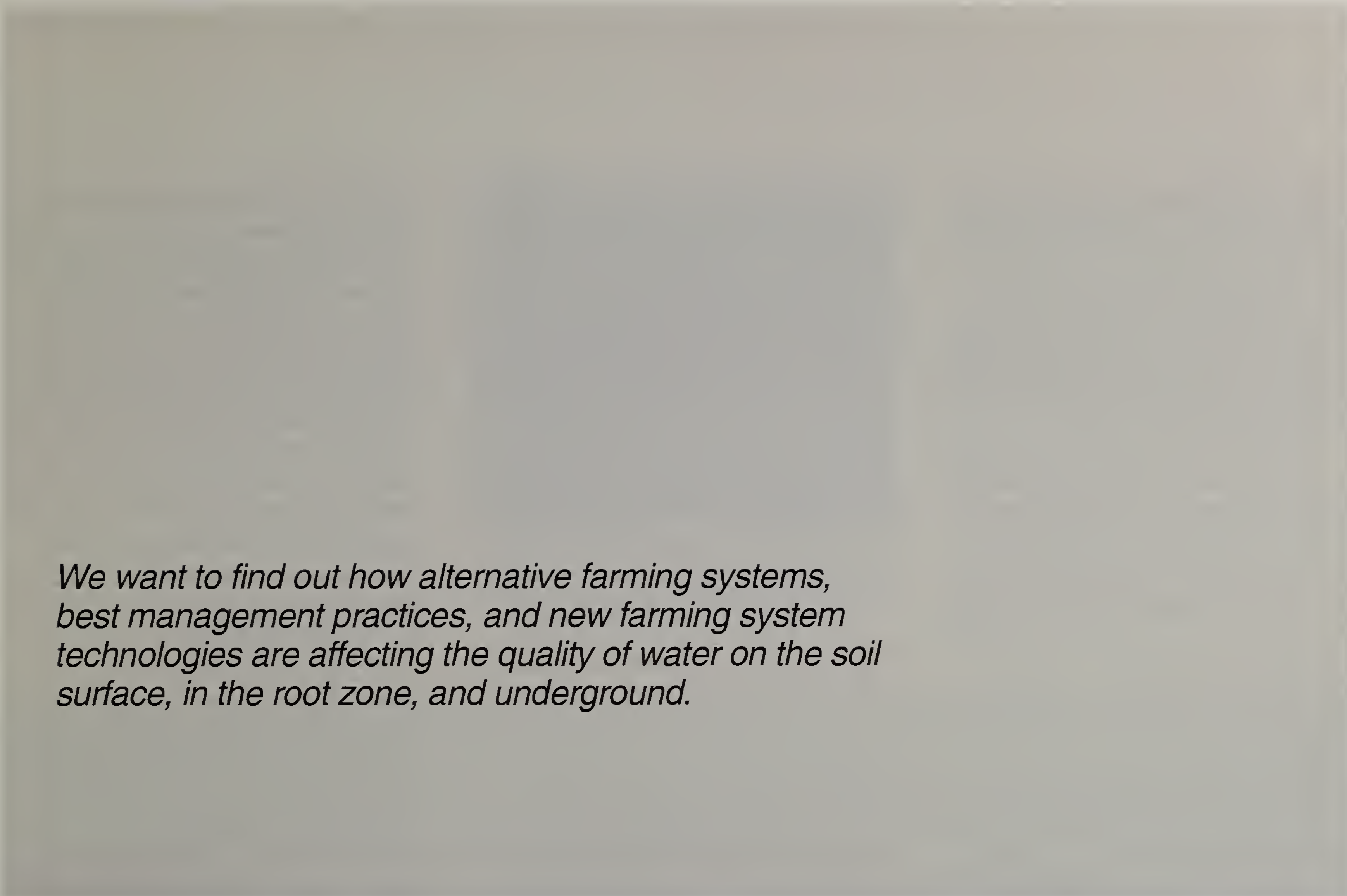


Midwest Water Quality Project Matures



We want to find out how alternative farming systems, best management practices, and new farming system technologies are affecting the quality of water on the soil surface, in the root zone, and underground.

Follow the route of ancient glaciers on a ride with Steve Workman south along U.S Route 23, down the center of Ohio from Columbus to Piketon, and you'll learn a lot about farming and clean drinking water.

Workman is an agricultural engineer hired by USDA's Agricultural Research Service to oversee the daily operations of a groundwater quality project on John Van Meter's 650-acre corn/soybean farm in Piketon.

As he leaves Columbus, Workman points to six small concrete buildings along the Scioto River, which Route 23 crisscrosses for 80 miles until it reaches the Ohio River at the Kentucky border. "Those buildings house wells that pump water from the Scioto River Valley alluvial aquifer to supply some of Columbus' drinking water," he says.

At the Walnut Creek watershed in central Iowa, technician Sharon Hanson samples surface runoff and water flowing out of tile lines under farm fields to measure pesticide and nitrate levels. (K4521-9)

Workman notes that many cities in the United States were built near major rivers for easy transportation. Now populations have increased to the point that the groundwater found in the river valleys is needed to supplement surface supplies. In the midwestern United States, alluvial aquifers provide 90 percent of the drinking water for rural homes and about 40 percent of the urban supply.

The Ohio groundwater quality project is located above one of these alluvial valley aquifers, on 135 acres of the Van Meter farm leased by USDA. It is part of a larger departmental effort to address the public's growing concerns about the effects of farm pesticides and nitrogen from fertilizer and other sources on water quality. This departmental research and education project is known as the Management Systems Evaluation Area (MSEA) program.

The MSEA project focuses on the Midwest Corn Belt and involves eight states: Ohio, Iowa, Missouri, Minnesota, North Dakota, South Dakota, Wisconsin, and Nebraska.

Sites in the project, which is part of the USDA Water Quality Initiative, have varied susceptibility to groundwater contamination, depending on soil types and underlying geologic materials. Begun in late 1989, the initiative receives congressional funding for a coordinated seven-agency program.

Dale Bucks, ARS national program leader for water quality, says the initiative, designed to help farmers comply with voluntary state water quality provisions, is in its fourth year of research and development. "We want to find out how alternative farming systems, best management practices, and new farming system technologies are affecting the quality of water on the soil surface, in the root zone, and underground," he says.

"We're beginning the phase now of extending our results to a regional scale, which is the kind of information state environmental agencies need to do

their jobs. We're also beginning to deliver technology to farmers that will help keep chemical levels within Environmental Protection Agency (EPA) guidelines. Information is being relayed to farmers through newsletters, field days, workshops, conferences, media publicity, and surveys."

The water quality initiative involves a close cooperation between USDA research agencies—ARS and the Cooperative State Research Service—as well as with the Soil Conservation Service and Extension Service, which are directly involved with farmers. The cooperation also extends to state universities, as well as to other state and federal agencies such as the U.S. Geological Survey (USGS) and EPA. Funds are pooled from the state, USDA, USGS, and EPA. Environmental and private organizations such as the Leopold Center for Sustainable Agriculture in Iowa are also involved.

BRUCE ZAKE

Agricultural engineers Steve Workman (foreground) and OSU's Sue Nokes, with student Gabriel Senay, evaluate the growth stage of ridge-till soybeans. (K5224-1)

"The USDA Water Quality Initiative brings the expertise and money needed to study water quality on an ambitious scale," Bucks says. "It brought funding to pay scientists such as Workman in Ohio and to install the wells needed at each site—as many as 150 in just one Iowa watershed."

An Integrated Project in Ohio

"USGS has worked closely with us in characterizing the Scioto River Valley alluvial aquifer," Workman says.

The aquifer has about 80 feet of sand and gravel deposited by drainage of meltwater from Pleistocene glaciation, with a supply potential of 1.4 billion gallons per day. The water table normally ranges from 5 to 20 feet below the soil surface. Workman explains that USGS is concerned with deep groundwater, whereas USDA's primary research interest traditionally extends only as deep as a crop's roots and to shallow groundwaters.

Typical of both the intense monitoring and close interagency cooperation, Ohio State University graduate student Abe Springer and Martha Jagucki, a USGS geologist in charge of well drilling, lived on the Van Meter farm for 2-1/2 months in the winter of 1990/91. They sampled the geological strata every few feet, as 41 wells were drilled in and around the area leased. Twenty-two of these wells have multiple ports for sampling, allowing for 108 sampling locations in the aquifer.

Numerous wells, drilled to various depths, are scattered throughout the research fields in different geological strata to monitor water levels and chemical concentrations. Some are computerized to take measurements automatically every half hour.

Soil moisture probes and other instruments track soil water movement and quality in crop root zones. Soil and water are thoroughly monitored for levels of four to six major herbicides and for nitrates from nitrogen fertilizer, manure, and other sources.

Three farming systems—continuous corn, corn-soybean rotation, and corn-soybean-wheat/hairy vetch rotation on ridges—are being evaluated for water quality impacts and economic viability.

Norm Fausey, the ARS soil scientist in charge of the Ohio research, says that five farmers in the Scioto River watershed have lent sites for demonstrations to show how actual farmers fare with the practices being tested on three 25-acre fields and eighteen 1-acre plots on the Van Meter farm.

Routine sampling every 2 to 4 weeks includes groundwater from wells, soil water from lysimeters, aboveground plant biomass and nitrogen content, and soil, to determine water content and agrichemical concentrations. Other periodic measurements include root length, canopy cover, crop height and population, pest infestation, and weed biomass.

KEITH WELLER

Ohio State University technician John McCormick collects deep soil core samples for chemical analysis while ARS technician Steve Colegrove takes notes. (K5192-2)

Fausey says that the Ohio MSEA has a very strong program investigating the influence of farm management systems on soil biological and ecological processes. Clive Edwards and Scott Subler, soil ecologists with Ohio State University (OSU), are monitoring nitrogen as it cycles through plants and soil. They are studying the activity of soil organisms and microorganisms that play a critical role in the process.

Automated weather stations in the fields keep local records around the clock. Thousands of soil samples taken from depths of 4 feet or more are

KEITH WELLER

As part of the ridge-tillage system practiced at the John Van Meter farm, OSU assistant farm manager Wayne Lewis cultivates for weed control in soybeans. (K5197-3)

frozen and sent to the ARS National Soil Tilth Laboratory at Ames, Iowa, for analysis.

The Iowa lab is fitted out with robotic equipment for 24-hour-a-day soil analysis. Each robotic system can handle 40 tubes of samples at a time, the equipment automatically performing the many steps involved in pesticide extraction. Local water quality labs analyze water samples following strict quality control standards.

Even rainfall is sampled for herbicide and nitrate content. Plants are

A Dip-Stick Test for Soil Nitrogen

Scientists in the Nebraska MSEA unit are evaluating a "last-minute" soil nitrate test as a promising means of reducing nitrogen use by corn farmers.

The overnight test, called the presidedress soil nitrate test (PSNT) was developed by University of Vermont researcher Fred Magdoff. It is done after the corn has grown about a foot tall, rather than before planting as is traditionally done. The test allows farmers to avoid applying large quantities of fertilizer at planting time, based on estimates of what might be appropriate. Instead, it tells them if soil nitrogen is adequate for the crop, or if sidedress nitrogen is needed.

Corn uses large amounts of nitrogen, phosphorus, and potassium—the key ingredients in commercial fertilizers. But the only thing constant about nitrogen is the fact that it's always moving and changing.

When fertilizer nitrogen is added to corn before planting, the nitrogen can leach through the soil and be lost or tied up by soil microorganisms before the plant is ready to use it. So farmers from east to west who planted an estimated 76,486,000 acres of corn for grain use in the 1993 crop year have planned their nitrogen applications carefully—whether, when, and how much to apply.

ARS soil scientist James S. Schepers in Lincoln, Nebraska, serves on a regional committee that devotes at least half its time to evaluating the PSNT. The committee is made up of ARS and university researchers from Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Ohio, Nebraska, North and South Dakota, and Wisconsin.

Schepers and University of Nebraska researchers have been evaluating the test for the last 6 years. It has been in limited use east of the Mississippi for about 9.

Each PSNT sample is taken from a 1-foot depth, dried overnight, and mixed with an extraction solution provided in the test kit. A nitrate test strip is dipped in the solution and then checked with a digital meter that indicates the color intensity: the more purple, the more nitrate is in the sample.

Commercial soil testing laboratories can also perform this chemical test.

In Beltsville, Maryland, ARS soil scientist Jack Meisinger, who works with the regional committee, has been evaluating the test in cooperative studies with the University of Maryland in an effort to reduce nitrate concentrations that end up in the Chesapeake Bay.

"It really helps identify fields that don't need extra nitrogen fertilizer," Meisinger says.

Schepers also uses a chlorophyll meter to check corn for greenness, which indicates nitrogen status. It gives farmers guidance as to when to add liquid nitrogen to irrigation water. More than 5 million acres of corn are irrigated in the state of Nebraska alone, so fine-tuning inputs could reduce costly excesses.

But he says that using the chlorophyll meter doesn't mean that farmers shouldn't apply starter fertilizer. "With this method, early-season application of nitrogen is still needed to get the plant to 18 inches in height. That's when the chlorophyll meter becomes reliable and remains a good management tool until after corn silking," says Schepers.—By **Linda Cooke,** ARS.

dried in ovens, weighed, and analyzed for nutrients and chemicals. Roots are washed, weighed, counted, and measured. Liquid manure used in the corn-soybean-wheat/hairy vetch rotation is analyzed for nutrient content before application.

According to Workman, "Results to date show that the herbicides applied in 1991 have not moved below the top 12 inches of the soil, and nitrogen applied in 1991 as fertilizer has not reached the shallow water table in the aquifer as of June 1993."

KEITH WELLER

OSU graduate student Chris Finton uses a computer model to calculate flow paths and velocities of groundwater moving from 25-acre research plots towards the Scioto River. (K5190-4)

OSU soil physical chemist Sam Traina and graduate student Mark Radosevich have isolated a soil microbe that degrades atrazine and its metabolites. And Fausey's counterpart at OSU, Andy Ward, says that the low-chemical-input, ridge-till-based rotation of corn-soybean-wheat/hairy vetch looks very promising from an economic standpoint, because costs are lower and there has been no difference in corn yield compared to the high-input continuous corn rotation.

In Iowa, the Focus Is on Runoff

Jerry Hatfield, head of the National Soil Tilth lab and principal investigator for the Iowa MSEA, says that runoff from heavy spring rains carried high concentrations of atrazine to tributaries of Walnut Creek in central Iowa. "These concentrations are short-lived, lasting a day or two after a rainstorm," Hatfield notes.

Hatfield says his team is evaluating different tillages to see which reduce surface runoff best. They are also testing a nitrogen management system that includes dividing fertilizer applications into several small applications. Such split applications can reduce nitrate in groundwater from more than 20 parts per million (ppm) to near 10 ppm without putting a dent in farm profitability.

The team also found that farmers can lower their fertilizer losses by making more accurate estimates of what their crops will need during the growing season.

Fertilizer applications are usually based on yield projections that may not be met because of weather or other variables. Hatfield says that over the past 12 years of research at the Treynor watersheds in southwest Iowa, farmers reached their yield goals only once. "The high soil nitrate levels we found were due to applications for a yield that was hardly ever realized," he says.

The MSEA project also includes a third major site in northeastern Iowa.

So far, results from the Iowa research show that atrazine and other herbicides are concentrated in the upper foot of topsoil, while nitrate is more uniformly distributed throughout the 4-foot depths sampled eight times a year.

Nitrate concentrations in underground tile drainage lines vary between 10 and 20 ppm, while herbicide concentrations are generally below EPA guidelines. Herbicide levels in shallow wells also fall within guidelines.

Hatfield and colleagues are mapping landscape variations in nitrate and atrazine levels, organic matter and other soil properties, and crop yield across fields in the 12-square-mile Walnut Creek watershed. He says that nitrate infiltration is very dependent on the geologic structure of the area.

For example, nitrate in water moves very slowly through the glacial till layers of the Walnut Creek watershed. Very little reaches deep. At levels below 50 feet in the Walnut Creek watershed, nitrate concentrations are less than 2 ppm. This watershed "has soil conditions representative of a quarter of the state," Hatfield says.

He says that research on sites much larger than normal research plots makes the results from all MSEA sites more transferable and credible to all types of farmers.

"With commercial-size fields, we can let farmers do the farming for us, with their own tractors and equipment," he says. "All the fields in the Walnut Creek watershed are operated by farmers. We give them a concept such as no-till with postemergence weed control, and they offer suggestions on ways to adapt the concept to a particular field. This is instant technology transfer."

Iowa farmers are meeting in focus groups to more formally evaluate the practices and technologies being tested and demonstrated. Hatfield says that sociologists and economists are also interviewing farmers throughout the Midwest to understand what it takes to get farmers to adopt new technology and alternative methods.

This year, the Iowa scientists began experiments with two postemergence herbicides, Accent and Pursuit, that would eliminate the need for preventive treatment before planting.

Similar tests of more environmentally friendly alternative herbicides are being done throughout the Midwest. For example, soil scientist William C. Koskinen, of St. Paul, Minnesota, found that in field tests the postemergence herbicide sethoxydim and its breakdown products leached more slowly than did atrazine or alachlor. Applied at one-tenth the rate of those herbicides, sethoxydim is quickly destroyed by light and water or is broken down by soil microbes soon after killing the weeds.

RICHARD NOWITZ

At the National Soil Tilth Laboratory in Ames, Iowa, chemist Richard Pfeiffer prepares a soil sample for placement in the roboticized pesticide extractor. (K4520-9)

Meanwhile, Precision Farming in Missouri

In Missouri, ARS soil scientist Gene Alberts says that like Iowa, "we are working with many farmers in the 28-square-mile Goodwater Creek watershed. We have a farmer who is farming three fields for us, each 50 to 90 acres in size. The farmer maintains records of labor; costs of herbicides, fertilizer, other inputs, and machinery; and grain yields and prices. We're using these and other records to assess the profitability of each farming system."

Missouri researchers have developed a laboratory procedure to detect breakdown products formed as the herbicide atrazine degrades. To their surprise, they found these products in streams. They had thought the breakdown products were bound too tightly to soil to move into streams.

Agricultural engineers Kenneth A. Sudduth at Columbia and John W. Hummel at Urbana, Illinois, are working with AGMED, a Springfield, Illinois, company, to develop a portable near-infrared reflectance sensor that measures soil moisture and organic content. The sensor will aid in prescribing correct amounts of soil-applied herbicide. The higher the organic content, the less likely the herbicide will be to leach and the more herbicide can be safely applied.

Alberts says that one strength of the Missouri project lies in assembling various technologies and tools into a prescription farming package. He says that all of the Midwest states in the project are finding ways to prescribe more precise applications of farm chemicals that take into account both plant needs and soil vulnerability to chemical leaching. Prescription farming techniques being developed in these states are contributing to a nationwide interest in the method.

The Missouri scientists have developed a tractor-mounted sensor that can detect claypan soil layers. Common in Missouri and other parts of the country, claypan inhibits yield by restricting root growth.

"We're mapping yield and soil variability within a field, as well as the claypan," Alberts says. "We want to relate these to each other and understand field variability and how it affects the movement of herbicides and nitrate to surface and groundwater."

BRUCE FRITZ

In Missouri, corn is harvested by a combine that is linked to the satellite-based Global Positioning System. Precise yield and location data will be correlated with soil samples taken earlier at sites throughout the field. This information will help growers plan optimal fertilizer rates for the next crop. (K4912-11)

Tillage Systems in the Northern Cornbelt Sand Plains

Robert W. Dowdy, ARS research leader in St. Paul, Minnesota, says the Northern Cornbelt Sand Plains MSEA project involves Minnesota, North Dakota, South Dakota, and Wisconsin. "The relatively coarse-textured, low-organic-matter soils in this project allow surface water to move down to groundwater fairly rapidly."

Dowdy says that the Northern Cornbelt Sand Plains study is unique because he and his colleagues are studying the same corn/soybean farming system in four states, representing a broad cross-section of soils, climate, and production practices for comparison. "This farming system involves several seldom-used practices that, when packaged into one system, reduce demand for herbicides and fertilizers."

The system consists of applying atrazine and alachlor herbicides in a narrow band, which reduces total chemical use by two-thirds. It also involves nitrogen application on an "as-needed" basis, irrigation timing and quantity based on crop demand, and ridge tillage.

Ridge tillage involves growing crops on raised seedbeds. Farmers typically apply fertilizers and herbicides to the ridges and control weeds between ridges by cultivating.

At the principal research site in Minnesota, this total cropping system is being compared with a more conventional corn production system using full-width tillage, herbicide sprayed across fields, and typical nitrogen applications.

Dowdy says that no atrazine or alachlor attributable to either cropping system has yet been detected in groundwater.

But John A. Lamb, University of Minnesota soil scientist, says that nitrate levels have increased in groundwater under conventional cornfields. He also reports that nitrogen uptake by plants can vary by as much as 35 pounds per acre over a distance of 800 feet in the fine sandy soil that is not as uniform as it looks.

Another source of variability, Dowdy says, is associated with the fact that rainfall moving through the crop canopy (throughfall) is not uniformly delivered to the soil surface. The least throughfall occurs on the downwind side of ridges in the ridge-tillage fields. Cropping systems can be designed to take advantage of this situation to minimize leaching of chemicals. "One example is placing fertilizer on the downwind side," he says.

ARS soil scientists working with University of Minnesota colleagues are measuring soil water distribution in two dimensions, using time-domain reflectometry (TDR). TDR is a modern technique using radar signals sent through electrical cables to measure water movement. So far, their data confirm the throughfall distribution patterns noted by Dowdy. The technique is also providing information needed to develop predictive models that extrapolate data to other regions of the country.

"Through further studies on the placement of agricultural chemicals, application rates, and tillage practices, we hope to help farmers increase crop production efficiency while minimizing the pollution hazard," Dowdy says.

And in Nebraska, Managing Water and Nitrogen

Similar results are coming out of Nebraska. Jim Schepers, the ARS project leader in Nebraska, says that the combination of irrigation with sandy, highly permeable soils makes aquifers in his state particularly vulnerable to nitrate contamination.

Schepers says the researchers have found ways to strategically add nitrogen to irrigation water after analyzing for plant nitrogen status. The addition of nitrogen to irrigation water is currently being used by farmers, but often without monitoring for actual plant needs.

"Instead of applying 150 pounds of fertilizer per acre all at once," Schepers says, "we add just enough to start the

seedlings out and then add more once a week or so, but only if plant tissue monitoring calls for it."

"The combination of improving irrigation techniques and adding nitrogen to irrigation water has reduced both water and nitrogen use by up to 50 percent, compared to current practices," he says. "We're finding reduced levels of nitrate in groundwater after 2 years."

Schepers says another strategy under evaluation is placing nitrogen in alternate rows and irrigating only those rows without nitrogen so it is not moved out of the root zone by the water.

"We are also testing deep-rooted crops like alfalfa in rotation with corn, to scavenge nitrate left in the soil."

KEITH WELLER

Wheat grown on ridges at the Ohio MSEA site is part of a 3-year rotation with corn and soybeans. (K5196-2)

Putting It All Together

ARS' water quality program leader Bucks says the strength of all the MSEA projects is that they look at the ecosystem as a whole, instead of having individual researchers working on different parts of a system at different locations, with little communication.

"We're studying farming practices and chemicals and their interactions with plants, the soil, soil organisms, and surface and groundwater quality. We're learning that there is considerable variation up and down, as well as side to side, no matter how close or similar two locations are."

Bucks points out that researchers in all the MSEA's have worked together from the beginning of the project to develop common sampling methods and techniques. This uniformity aids in sharing information among the sites.

One common finding has been that herbicides are more often found in streams and lakes, while nitrate is more common in groundwater.

"We're finding that nitrate-nitrogen levels in groundwater periodically exceed the EPA guideline for drinking water—10 parts per million—at certain locations in all the states studied, with levels of 30 to 40 ppm more common in the irrigated sands of Nebraska," he says. "And Iowa has found nitrate levels as high as 35 ppm in streams after heavy spring rains.

"We generally aren't finding any herbicides in deep groundwater, but we've detected some in shallow groundwater," he says. "In surface water, we've found atrazine levels as high as 75 parts per billion (ppb) in spring runoff in Iowa, with 3 ppb being the EPA guideline for drinking water. We've found metolachlor levels up to 29 parts per billion, above the EPA guideline of 10 ppb. But the seasonal averages of it and the other herbicides are usually below EPA guidelines. We must recognize that there is tremendous variability in the timing, amounts, and distribution of herbicides being found in surface and groundwater."

Bucks says that "to transfer technology to farmers, people in different agencies and disciplines—ecologists, agronomists, soil scientists, engineers, geologists, computer modelers—have to talk to each other and combine their work into a package farmers can use.

"Besides the unusually extensive instrumentation and sampling involved, the MSEA projects are unique in that they approach research problems from a variety of perspectives. For example, soil ecosystem scientists examine the effects of different practices on soil biological processes. The results of their work are in turn used by soil physicists and agricultural engineers to model the movement of nitrates under fields. This information is then combined with that of hydrogeologists who evaluate nitrate transport in groundwater under entire landscapes.

"In this way," Bucks says, "a complete picture is developed of the movement of nitrates and herbicides from the soil surface to deep aquifers and across crop rows and landscapes. The ecosystem perspective requires integrating diverse research activities into a meaningful whole."—By **Don Comis,** ARS. **Ben Hardin,** ARS, also contributed to this article.

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Shrinking Screwworm's Domain

ARS Assists FAO in Groundwork for Eradication Effort

Spanish explorers called it "the worm of death" four centuries ago. And while it's only a memory today for longtime U.S. ranchers, the flesh-eating screwworm is still a scourge in parts of South and Central America and the Caribbean.

In those areas, in the jungle and on the farm, the screwworm abounds.

It is one of the most cruel and costly insect pests of livestock and wildlife. Adult screwworm flies lay eggs in the open wounds of live mammals, including humans. Larvae hatch from the eggs and use sharp, toothlike mouth parts to shred the flesh and feed on the softened tissue.

The larvae usually feed for 5 to 7 days; if unchecked, they can kill an animal. When finished feeding, the larvae drop to the ground and work their way into the soil to pupate. The life cycle lasts several weeks, but varies depending on weather and other conditions.

The pest caused an estimated $100 million damage annually in the United States before its 1966 eradication using insect control technology developed by ARS scientists. The last U.S. infestation introduced from outside the country was eradicated in 1982. And it was eradicated from Mexico in 1991. But the pest still causes millions of dollars in damage to livestock and wild mammals in Central and South America and in the Caribbean—and there's always the chance that it could again enter the United States.

So ARS scientists are helping to lay the scientific groundwork for a screwworm eradication program in those regions. The researchers are working in partnership with the Food and Agriculture Organization (FAO) of the United Nations, which is coordinating an effort to eradicate the pest in the Caribbean.

"ARS is the world leader in screwworm research and we want to have the best tools available to us before we begin an eradication program in the Caribbean," says Moises Vargas-Teran, an FAO animal health officer who met with agency scientists in February to discuss the research partnership.

JOHN KUCHARSKI

Technicians at the Animal and Plant Health Inspection Service's screwworm mass-rearing plant in Tuxtla Gutierrez, Chiapas, Mexico, check developing insects in sawdust-filled trays.

APHIS

Screwworm fly.

Ralph Bram, ARS national program leader for medical and veterinary entomology, says USDA's Animal and Plant Health Inspection Service is also continuing its effort to wipe out the screwworm in Central America, in cooperation with countries in that region. FAO is undertaking the planning of an international effort to battle the fly in the Caribbean. An eradication program in the Caribbean could begin once the research projects are completed and international support is obtained, probably in 1995, Vargas-Teran says.

The Sterile Male Release Strategy

ARS achieved its worldwide reputation for screwworm control based on the pioneering work of Edward F. Knipling and Raymond C. Bushland, who devel-

oped the sterile male release strategy. [See "Subduing the Screwworm," *Agricultural Research,* July 1992, pp. 6-7.] For their discovery, these scientists were awarded the 1992 World Food Prize.

The sterile male strategy works like this: Millions of screwworm flies are mass-reared each week in a facility in Tuxtla Gutierrez, Mexico, and then subjected to radiation—not enough to kill them, but enough to make them sexually sterile. On release, the sterile males compete with wild, fertile males to mate with females. As more and more wild females mate with sterile males and lay eggs that do not hatch, the overall population shrinks and eventually dies out .

Use of this strategy eliminated the pest from the United States and Mexico. And FAO used the technology to eradicate the screwworm in Libya during 1989-92, preventing its spread to other parts of Africa, Europe, and the Middle East.

Does It Work in the Tropics?

Although successful in the United States, Mexico, and Libya, standard sampling methods for evaluating effectiveness of the sterile male release strategy may not work in the Tropics. Weather and other factors there present new obstacles to luring and trapping flies needed to gauge the strategy's effectiveness, Bram says.

The problem is that standard traps—the types used in the United States and Mexico—rely on wind to carry the bait odors. But in low-lying tropical forests that are the preferred habitats for screwworm flies, there is little if any wind. Bram says there are also other competing odors in humid tropical areas that aren't present in drier regions to the north.

So Frank D. Parker, an ARS entomologist based in Costa Rica, has been working on overcoming these obstacles. He's found a better way to lure adult flies with a new trap that emits attractant uniformly in all directions.

But before he could test the trap and bait, Parker and John B. Welch, an ARS scientist now based at the Center for Space Research at Austin, Texas, needed a standard against which to measure the trap and bait.

They devised a crude but effective tool: They trained technicians to sit with an insect net next to pieces of rotting beef liver. When screwworm flies landed on the liver, technicians captured them with the net, marked them with identification numbers, and released them. They recorded the time of day and climate conditions, such as temperature, rainfall, and humidity, hoping to determine the effects of weather on daily activity.

Then Parker set up the new trap, which is a flat disk covered with a sticky substance to catch the flies. At the center is a bait, called swormlure-4, a chemical attractant previously developed by ARS scientists. Parker says the sticky trap is as effective as the liver lure and can be used to sample and detect screwworm populations. APHIS tested the trap in Honduras.

FRANK PARKER

Technician David Molina captures and counts screwworm flies at a liver-baited fly-marking site in a tropical dry forest near Canas, Costa Rica.

Counting Sterile Eggs

But monitoring the number of adult flies isn't the only yardstick for gauging the effectiveness of the screwworm control program. Scientists must also know how many of the eggs that adult females lay are sterile or fertile. To find out, cooperators with FAO are developing what is called an "artificial wound."

Now the wounds of live animals have to be checked several times a day

to extract fly egg masses for analysis, to see if they are sterile—a time-consuming and labor-intensive process.

So scientists want to eliminate the need for live animals by replicating a wound artificially. Frederic Poudevigne, a French veterinary medical officer with the FAO in San Jose, Costa Rica, has designed a prototype for field use.

It uses a heated water bath to warm up samples of cattle or sheep blood contaminated with the bacteria associated with screwworms.

The researchers are determining which combination of bacteria is most effective for attracting females. They will then do laboratory tests on several bacterial species to assess their effectiveness as attractants.

Confirming earlier ARS findings, Poudevigne says that a wound's pH level has a significant impact on whether or not the insect will lay eggs in it. "It seems that the fly checks the wound to determine its suitability for the larvae," he says.

A chemical buffer, PBS (phosphate buffered saline), is added to stabilize the pH level at 7.4 in the artificial wound. The temperature of the mixture—what he calls the "oviposition medium"—is 104°F (40°C). A 12-volt battery powers a small heater, which is controlled by a thermostat.

"We have obtained excellent results in laboratory studies," Poudevigne says, adding that future field tests of the artificial wound are planned.

Poudevigne is cooperating in Costa Rica with Isidoro Ruiz Martinez, an entomologist from Spain conducting research under a Fulbright grant. They will study temperature, pH, competition among screwworm larvae, and other subjects. Martinez is also working with Robert Matlock, an ARS scientist based in San Jose, to study the sounds that screwworm flies and other species make. They say the results could help improve detection and trapping methods.

FRANK PARKER

Sticky trap for monitoring screwworm fly populations in the Tropics.

Computer Modeling

Another component of the research effort is a computer model, called SWFSIM (Screwworm Fly Simulation Model), that will be developed to predict screwworm population densities, based on weather and other factors. Danel Haile, an agricultural engineer at the ARS Medical and Veterinary Entomology Research Laboratory in Gainesville, Florida, is working with Matlock to develop the model.

Haile says the model takes into account primarily weather—temperature, humidity, and rainfall—as well as the number of animals (livestock and wild) in a given area. The model also assumes that one-half of 1 percent of the animals will have wounds that could be infested with screwworm larvae.

The main factors, he says, are temperature and rainfall. Screwworm flies thrive at temperatures between 75°F and 79°F. Populations drop if it gets too hot, and if it's too cold, the pest can't survive the winter.

"Primarily, we can predict the seasonal patterns of the screwworm population from these two factors," he says. "We've calibrated the model based on actual data from previous infestations in Texas and Libya, so we have some confidence in its predic-

JOHN KUCHARSKI

Technicians treat a calf's screwworm-infested umbilical.

JOHN KUCHARSKI

A technician monitors the temperature in a screwworm larval-rearing vat.

tions. Time and experience with the model in other locations will improve its accuracy."

By early 1994, Haile says, he and Matlock will have completed a model that can predict screwworm populations in Costa Rica and other countries in Central American and Caribbean regions. The model will also simulate control, based on how many sterile males are released at a given time.

"The important thing is that the model combines what is known about screwworm biology and control into one software package that will show countries that the eradication technology works," says Haile.

Population Genetics

How closely related is a screwworm in Brazil to one in Jamaica? ARS researchers in Lincoln, Nebraska, are seeking answers to this and other questions as they gear up to look at the genetic differences of screwworms from the Caribbean and Central and South America.

This research will include genetic "fingerprinting" to gain a better understanding of the pest's distribution patterns so that, if an outbreak occurs, "we'll know where it came from," says David Taylor, an entomologist with the ARS Midwest Livestock Insects Research Laboratory at Lincoln, Nebraska.

To identify screwworms, Taylor says they are focusing on enzymes, called isozymes, and on DNA material. Both are inherited from the insect's parents—just as humans inherit eye and hair color from their parents.

Knowing the origin of a screwworm outbreak is quite important, Taylor says, because it may help identify a "leak" in a quarantine zone. "Where did the quarantine system break down so that Libya got the infestation?" Taylor asks.

It's also important because sterile flies that are reared for release need to be matched to native flies in a particular area. "We know very little about screwworm flies in South America, for example," he says. "When we release sterile flies, we want to make sure they are compatible and will mate with wild populations. Otherwise, they won't be effective."—By **Linda Cooke** and **Sean Adams,** ARS.

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For information on the FAO research, contact Moises Vargas-Teran, FAO-UN, Rome, Italy; phone 57973977. ◆

Erosion Takes a Powder

An inexpensive white powder can help save valuable topsoil and stem water pollution.

Agricultural Research Service scientists say the powder—called polyacrylamide (PAM)—prevents irrigation water from carrying away soil particles as the water flows down a furrow. That could help halt the loss of more than 2 billion tons of soil that wash off the world's 600 million acres of irrigated croplands each year.

"Sediment loss has been reduced by up to 97 percent and water infiltration increased by about 25 percent during our tests, which started in 1991," says Robert E. Sojka of ARS' Soil and Water Management Unit in Kimberly, Idaho. Soil that erodes from fields costs farmers in lost productivity and it damages downstream environments.

"The PAM treatment also keeps fertilizers and other chemicals—as well as the soil—on fields where they belong," he adds. "That means the chemicals can't run off and harm fish and other aquatic life."

Sojka and fellow soil scientist Rick D. Lentz have found that as much powdered PAM as there is in a shake of salt from a salt shaker can treat a gallon of water. That's about 1 pound of powder per acre-inch of water. At about $1.25 per pound, an average irrigation costs $2 to $3 per acre.

DOUG WILSON

A handful of polyacrylamide will treat over 27,000 gallons of water—enough to cover an acre 1 inch deep. (K5231-7)

They have run tests on corn and edible dry bean fields to learn the best time to apply the minimum amount of PAM needed to stop the most soil loss.

The treatment has the potential in the United States to save soil on millions of furrow-irrigated acres of crops. With this system of irrigation, shallow trenches between crop rows transport water across fields.

PAM is a polymer—a chemical made up of molecules strung together in a chain—like polyethylene. Using polymers in irrigation water for erosion control was originally proposed by a visiting Israeli scientist, Isaac Shainberg.

PAM is nontoxic and nonirritating, according to scientists at Cytec, a division of American Cyanamid Corporation in Stamford, Connecticut, which makes the powder. It breaks down into water, carbon dioxide, and ammonia. A host of environmental factors control the breakdown rate, including the types and amounts of various microorganisms that degrade organic molecules and the availability of water and oxygen.

Water treatment facilities around the country already use polyacrylamide to remove suspended sediment as part of the purification process, explains Lentz. It works by making suspended particles stick together and fall to the bottom of the body of water, so they can be easily removed.

"We need to learn more about how PAM protects soil in irrigated furrows. The substance doesn't change how the water looks or feels, but it may alter the water's physical properties in subtle ways," says Sojka.

The scientists know that PAM-treated irrigation water greatly increases the bonding among soil particles in the wetted furrow. This strong bond prevents soil loss as water flows along the furrow.

The PAM treatment will be targeted to applications that will prevent the most erosion. These would be on fields with steeper slopes or for crops like edible dry beans and cotton that produce little soil-holding residue.

The researchers believe that at least 2 to 3 years of additional studies by soil scientists, chemists, and microbiologists are needed to test the long-term effects of the new treatment on soil and the fate of any treated water that may run off fields.

They are currently studying whether the treatment can benefit furrow-irrigated Russet Burbank potatoes. Some growers are switching to sprinkler irrigation because high-quality potatoes result only if they receive timely and even water delivery. Furrow-delivered water infiltrates soil less evenly, sometimes failing to sate thirsty tubers.

PAM-treated water from furrows might get to potato roots more evenly and produce high-quality potatoes comparable to sprinkler-irrigated ones. This could cut production costs, because furrow irrigation usually requires a lower capital investment and uses less electrical energy or fossil fuel.

Researchers are cooperating with Sherm Brewster, a local Idaho entrepreneur, to develop inexpensive equipment for adding PAM to water. One promising machine is powered by a water wheel that is rotated by waterflow in irrigation canals. They will also explore solar, battery, and direct-wired applicators.

The scientists believe PAM application is technologically easy enough to help developing countries that lack money and expertise needed for more complex anti-erosion measures such as land grading or changing to other crops.—By **Dennis Senft,** ARS.

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(K5231-1)

(K5131-2)

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(K5131-6)

[Left to right, top] ARS soil scientist Robert Sojka inspects water treated with polyacrylamide near the upper end of a 600-foot, sloped furrow. By mid-field, water in an untreated furrow has already picked up a large amount of sediment, while the PAM-treated water remains clear.

[Bottom] Sojka and soil scientist Rick Lentz use Imhoff cones to compare the sediment in runoff water taken from the end of an untreated control furrow to the clear, PAM-treated water. Adding just 10 parts per million of PAM reduced sediment in runoff from about 40 grams per liter to practically none. (Photos by Doug Wilson.)

The Cleanest Little Chicken House in America

Can you imagine living in an environment so clean and free of disease risk that you never get sick, take medicine, or need to be vaccinated?

"There are flocks of chickens that have lived at this laboratory, generation after generation, under just such conditions," says Charles W. Beard, the retired head of ARS' Southeast Poultry Research Laboratory, Athens, Georgia.

"This housing concept was developed at the Athens facility more than 20 years ago and is still evolving, as more sophisticated equipment and techniques become available," Beard says. "We call the system FAPP (filtered-air positive pressure) housing.

"We developed FAPP to supply chickens and fertile eggs for research on Newcastle disease, avian influenza, and infectious bronchitis, which cause heavy losses in infected flocks."

The system has been widely adopted by companies that produce eggs for use in growing vaccine viruses in germ-free embryonating eggs or cell cultures.

"The most important components of the FAPP system are clean air and positive pressure," says Bailey Mitchell, the agricultural engineer who designed and built the computer control system that runs the Athens FAPP facility. "Air entering the chicken house is filtered twice—first by a 35-percent-efficient filter and then by a 95-percent-efficient one. This ensures that no germ-bearing dust particles get in.

"The filtered air blown into the house raises the inside pressure. This positive pressure inside the FAPP house helps keep out unfiltered—and possibly germ-laden air—when the door is opened. Air blows outward, preventing unfiltered air from entering the facility," says Mitchell.

As an added precaution, workers in the FAPP houses do not go near any other poultry. "This is just one more way to ensure that the highly susceptible FAPP flocks with few natural antibodies remain free of disease. Caretakers must take showers and don clean clothes before entering the FAPP house."

ROB FLYNN

Filtered-air positive pressure (FAPP) houses are the perfect environment for raising disease-free chickens and eggs needed for research. (K5171-2) [Inset] In preparation for a new population of birds, animal caretaker Roger Brock attaches a water line to a poultry "drinker." (K5171-1)

Special air locks are used to remove eggs from the building and to take in feed. The birds eat only feed that has been heated by a pelleting process, and they sit on suspended slatted floors that allow the manure to drop through to sloped, concrete floors that are cleaned daily, says Mitchell.

"We also monitor the health of the chickens via blood tests, to be certain they haven't experienced infections," adds Beard.

The flocks begin as fertile eggs produced by previous FAPP flocks, which are hatched in the ultra-clean facility, brooded there as baby chicks, and held there for their productive lives.

Some eggs are also hatched to produce broiler and layer chickens for research on how they respond to vaccines and therapy designed to prevent or reduce disease losses. FAPP-raised chickens make such research more reliable and reproducible—for test results are not influenced or complicated by pre-existing infections.

Will the poultry industry ever expand the application of such special housing to include the hens that lay the eggs we eat or the broilers we barbecue for the backyard picnic? No one knows the answer to that question, but one thing is certain: FAPP housing, through its support of vaccine production and protection of valuable genetic stock, is already playing an important role in protecting our food supply.

The fact that nearly all disease-free chickens and eggs used worldwide for vaccine production and biological research are grown in FAPP houses speaks well for the value of this unique system first developed at this ARS laboratory.—By **Vince Mazzola,** ARS.

Bailey W. Mitchell is at the USDA-ARS Southeast Poultry Research Laboratory, 934 College Station Rd., P.O. Box 5657, Athens, GA 30604. Phone (706) 546-3443, fax number (706) 546-3161. ◆

Getting Cholesterol in A-1 Condition

Most people have become aware that there's a good cholesterol, HDL, and a bad one, LDL. But they often can't remember which is which.

Now, new terms for assessing cholesterol levels are emerging. A growing number of researchers believe that levels of specific proteins found in HDL and LDL are as good as, or better predictors of heart disease than the HDL and LDL values themselves.

HDL and LDL particles contain one or more kinds of proteins called apo's, short for apolipoproteins. The apo's usher the fatty particles through a host of metabolic processes. Apo A-I is the major protein in HDL; apo B is the only protein in LDL.

Since our genes code only for proteins, the apo's give a clearer picture of the hereditary influence on cholesterol levels, say researchers in the Lipid Metabolism Laboratory at the USDA/ARS Human Nutrition Research Center on Aging at Tufts University in Boston. They've been studying the distribution of apo's in human populations for close to a decade. [See *Agricultural Research,* May 1988, p. 11.]

A recent study conducted with sets of identical and fraternal twins finds that our genetic makeup has far more say over our LDL levels than it does over our HDL levels, according to principal researcher Stefania Lamon-Fava.

She says other studies on the heritability of HDL and its primary protein, apo A-I, have produced conflicting findings, causing much confusion. "Our findings suggest that apo A-I levels, and consequently HDL levels, are not very heritable."

The twins study also showed a strong genetic link for Lp (a), a lesser known fat-carrying particle that is associated with increased risk of heart disease.

Lamon-Fava and her colleagues collaborated with researchers from the Indiana University School of Medicine and from the National Heart, Lung, and Blood Institute, which provided some of the funding and all 222 sets of twins participating in its ongoing study.

They compared blood levels of specific apo's in 109 sets of identical twins—who come from a single fertilized egg—and in 113 sets of fraternal twins, from two fertilized eggs.

As seen in previous studies, says Lamon-Fava, "levels of apo B were much more similar in identical twins than in fraternal. This means that LDL levels are strongly determined by the genes." But similarities were much less distinct for levels of apo A-I, indicating that heredity plays a weaker role in HDL levels.

The researchers did not assess the volunteers' fat intake, which has been shown in other studies to have a far greater impact on LDL levels than on HDL. But they did measure body weight and noted the volunteers' exercise and alcohol consumption habits, which have also been found to affect HDL levels. These three factors and smoking accounted for 12 percent of the variability in apo A-1 levels, says Lamon-Fava, compared with only 1 percent in apo B.

"This indicates that people may improve HDL levels somewhat by not smoking, and by maintaining ideal body weight, exercising regularly, and consuming a moderate amount of alcohol—no more than a drink per day."—By **Judy McBride,** ARS.

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Hydrogenated Fats' Role in Cholesterol-Lowering Diets

A study by nutritional biochemist Alice Lichtenstein at the ARS Human Nutrition Research Center on Aging at Tufts in Boston, Massachusetts, shows that the semisolid, hydrogenated fats found in stick margarine are less friendly to the heart than the oils they come from.

When a group of men and women with moderately high cholesterol switched from a typical U.S. diet to a cholesterol-lowering diet, their "bad" LDL cholesterol dropped an average 17 percent. And the protein associated with LDL—which some believe is a better measure than the cholesterol value itself—dropped 20 percent. But these values declined only 10 percent each when researchers replaced the corn oil in the diet with corn oil margarine in stick form.

The oil also resulted in a more favorable ratio of total cholesterol to HDL cholesterol—the kind that protects our arteries from damage—than did the stick margarine. Substituting stick margarine for corn oil increased the amount of saturated fat in the diet more than 20 percent and resulted in a 10-fold increase in trans fatty acids.

Hydrogenated vegetable oils are found in margarine, solid cooking fat, crackers, cookies, and many other products, including fried fast food. In addition to being semisolid, they are less prone to oxidation. But the findings of this and earlier studies by ARS and other groups should encourage the use of unhydrogenated products when possible in cholesterol-lowering diets.—By **Judy McBride,** ARS.

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Mapping Blueberry Genes

Just as a road map shows a traveler the location and proximity of cities and towns, a genome map gives a scientist crucial information about the genes that control characteristics of a plant.

And now Lisa J. Rowland, a plant geneticist with the ARS Fruit Laboratory located at the Beltsville (Maryland) Agricultural Research Center, has developed an initial genome map for blueberries.

SCOTT BAUER

ARS geneticist Lisa J. Rowland collects leaf tissue from blueberry plants for DNA analysis and mapping. (K5181-1)

"A genome map shows a plant's chromosomes, along with the different genes or markers they contain," Rowland says. "The blueberry map currently comprises 12 linkage groups, which should represent the plant's 12 chromosomes."

To an untrained eye, the blueberry genome map looks like a chart with 12 different-length columns of numbers. The numbers are actually "names" that have been given to the genetic markers thus far identified by DNA analysis.

Rowland analyzed DNA samples from blueberry plants with both low and high chilling requirements, using a system called RAPD—Random Amplified Polymorphic DNA—to identify various genetic markers. Markers can be an enzyme, a piece of DNA, or some other visual trait. Since the pieces of DNA analyzed were random samples, they could belong to any of the 12 blueberry chromosomes. But from those DNA bits, Rowland and colleague Amnon Levi found 70 genetic markers that naturally segregate as the 12 linkage groups of the current blueberry map.

With the chromosomes well covered with markers, Rowland says it will be possible to follow them in blueberry plants and eventually use them to tag genes of special importance. She is especially interested in identifying markers linked to—located near—the genes that control chilling requirement.

The blueberry and other woody perennials form flower buds in the summer and fall. As days grow shorter and night temperatures lower, perennials go dormant and stop growing. This is the time when they develop the cold hardiness that makes them able to withstand the much lower temperatures of winter. Apple, pear, and peach trees go through this same process.

Rowland says the blueberry could be a model for these other woody perennials. She uses blueberries because the plants are small, are easy to maintain in a greenhouse or cold room, and have separate leaf and flower buds.

Depending on the variety, blueberries need between 200 and 2,000 hours of exposure to temperatures from 32°F to 45°F—their chilling requirement—

SCOTT BAUER

(K5183-2)

SCOTT BAUER

(K5182-18)

SCOTT BAUER

DNA strands isolated from blueberry leaves are the basis of mapping studies. (K5182-4)

for growth resumption and budbreak in the spring. Therefore, blueberries with a high chilling requirement cannot be grown in areas like southern Georgia and Florida. And varieties that now grow in these regions can't be grown farther north.

"Planting blueberry plants with chilling requirements appropriate to the areas in which they grow best is vitally important for fruit to be produced," Rowland says. "If we can identify and follow the genes that control these traits, then we can perhaps develop better strategies for breeding blueberry plants that would thrive and be productive in different climates."

In another project, University of Maryland graduate student Mubarack Muthalif is helping Rowland identify the genes—not simply markers located near them—responsible for both chilling requirement and development of cold hardiness.

"So far, we've isolated three proteins from blueberry buds that seem to correlate with cold hardiness," Rowland says. "We know this is true because quantities of these proteins increase when the plants become more cold hardy. Then, when buds open and levels of cold hardiness drop, the protein levels drop as well."

Muthalif has purified the proteins and identified one as cyclophilin.

"We know that cyclophilin is present in every living organism examined," Rowland says. "And in humans, it binds to the drug cyclosporin (an immuno-suppressant) and suppresses the immune system. In blueberries, we don't yet know what this protein binds to or what its function is."—By **Doris Stanley**, ARS.

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Natural Compounds Inhibit Decay Fungi

At the supermarket, plant physiologist Steven F. Vaughn viewed with dismay the moldy raspberries and strawberries—a sight he had seen many times before. He wondered if maybe there was something he and his ARS colleagues could do to extend the time berries resist the onslaught of fungi. If so, perhaps grocers and consumers could profit from riper and tastier berries than those that are picked early to prolong shelf life.

Vaughn and his coworkers at ARS' National Center for Agricultural Utilization Research, Peoria, Illinois, thought the problem called for a *fresh* approach.

"We thought we'd try surrounding the berries with a little extra amount of a natural antifungal compound they make themselves," he says. The idea was to continuously expose the berries in a closed package to a volatilizing compound—found in their aroma—that would not affect taste but would hold back the growth of three troublesome fungi, *Alternaria alternata, Botrytis cinerea,* and *Colletotrichum gloeosporioides.*

Vaughn and chemist Gayland F. Spencer tested 15 major volatile compounds—aldehydes, alcohols, ketones, and esters—that partially make up the aroma of raspberries and strawberries. To do this, they put fungi-inoculated berries into small jars fit into bigger jars containing filter paper soaked with small amounts of the test compounds. Then they sealed the large jars. At 50°F, five of the compounds, in concentrations as low as 400 parts per million of air, inhibited all three fungi on both raspberries and strawberries for at least a week in environmental chambers.

Of the compounds tested, 2-nonanone may have the most commercial appeal because it has a fruity floral aroma, does not break down quickly into other compounds, and costs little. Vaughn says that enough 2-nonanone to treat a quart of berries may cost less than a penny.

The researchers have applied for a patent on the use of all these natural compounds. However, commercialization would require further research to obtain U.S. Food and Drug Administration approval.

In other studies at the center, chemist Baruch S. Shasha and Vaughn entrapped 2-nonanone in cornstarch so it could slowly seep out to fungi-inoculated berries held in airtight flasks.

A week later, when the berries were unsealed, they briefly had a slight floral odor, but the fungi had not grown visibly. Fungi did grow when 2-nonanone was no longer around to protect the berries.

Partially ventilated packaging may be more desirable for the berries as they live and breathe in the supermarket, Vaughn says. Such an environment could prevent the fruit from developing off-flavors, while antifungal compounds would remain to prevent premature decay.—By **Ben Hardin**, ARS.

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Peanut's Flavor Source Revealed

Roasted peanuts probably owe their rich, nutty aroma to a blend of about a dozen natural compounds.

With the help of precision lab instruments and the sensitive noses of volunteer "aroma panelists," ARS chemists Gary R. Takeoka and Ron G. Buttery have pinpointed chemicals crucial to peanuts' pleasant flavor. The scientists are with the Western Regional Research Center in Albany, California.

Their work differs from previous peanut analyses that identified some flavor chemicals but didn't rank their importance. Takeoka and Buttery ranked 25 key flavor compounds. Of these, two weren't known to occur in peanuts.

One of the two was identified earlier as a part of popcorn and tomato aroma but hadn't been recognized as key to peanut taste.

Planters Life-Savers of Suffolk, Virginia, funded part of the research and provided more than 50 pounds of oil and dry-roasted peanuts for Takeoka and Buttery to analyze.

JACK DYKINGA

Chemist Gary Takeoka inserts a tube into a container of peanuts to isolate volatile flavor components for analysis. (K5143-1)

The findings could be used to enrich the flavor of roasted peanuts and other products by adding back compounds that impart aromas sometimes lost in processing. A prime target for flavor improvement: low-fat peanuts, because some components that contribute to flavor are in oil that's removed.

Too, peanut breeders could use the ratings to screen new peanut varieties for flavor.

Why study aromas to track key flavor compounds? Takeoka and Buttery maintain that aroma, not taste, is the most important part of flavor.—By **Marcia Wood,** ARS.

Gary R. Takeoka and Ron G. Buttery are at the USDA-ARS Western Regional Research Center, 800 Buchanan St., Albany, CA 94710; phone (510) 559-5668; fax (510) 559-5777. ◆

Irrigation Delivers Biocontrol, Along With Water

A natural biocontrol virus can be mixed in irrigation water to kill insects that cause major damage to corn and cotton, Agricultural Research Service scientists report.

A nuclear polyhedrosis virus sprayed on corn from overhead sprinklers reduced corn earworm larvae by 25 to 100 percent, depending on the timing and rate of virus application, according to ARS field studies conducted last year in Tifton, Georgia.

"This new approach to applying the virus is more cost-effective for growers because they can combine irrigation and pest control," says entomologist John J. Hamm. He and entomologist Laurence D. Chandler, also at the Tifton lab, conducted the research.

The virus affects only the targeted *Helicoverpa (Heliothis)* species of insects, among the most serious agricultural crop pests. The scientists say it is harmless to other insects and to humans and other mammals.

Once the virus is sprayed, insect pest larvae eat it and die within 3 to 5 days, depending on the dosage. The virus infects the larval tissue and produces an enzyme that dissolves the larvae. "It sort of melts them," Hamm says, adding that the virus then spreads to other targeted insects in the field.

Hamm says the virus was most effective when applied once when the corn formed tassels and three times when the silks began to form.

The *Heliocoverpa* insect reduces corn yields about 15 percent per acre in areas where it's a pest. When the virus knocks down levels of the insect in corn, it helps with later plantings of cotton and other crops, since the same species of pests attack those crops.

"Corn gives these pests a protected niche, because the larvae are covered by the husks—which leads to a new generation that attacks cotton," he says.

Hamm and Chandler say they hope the findings spur commercial interest in using this and similar viruses as alternatives to chemicals for controlling corn and cotton insect pests.—By **Sean Adams,** ARS.

John J. Hamm and Laurence D. Chandler are with the USDA-ARS Insect Biology and Population Management Research Laboratory, P.O. Box 748, Tifton, GA 31793; phone (912) 387-2323/2326, fax (912) 387-2321. ◆

Science Update

Gravity Table Separates Low- and High-Protein Wheat

A machine called a gravity table may net higher prices for soft white winter wheat exported from the northwestern United States to Japan and other Pacific Rim countries. This could happen next year if this new ARS grain quality assessment method passes further tests. The gravity table separates those wheat kernels that are lowest in protein. Pacific Rim millers may pay more for low-protein wheat because they can turn it into the best flour for steam breads, sponge cakes, and other foods. Gravity tables are already used to separate small or broken kernels from those suitable for planting as seed. *Dale E. Wilkins, USDA-ARS Columbia Plateau Conservation Research Center, Pendleton, Oregon; phone (503) 278-3292.*

Insulator Keeps Genetic Wires From Touching

With a special insulator, a newly inserted gene is more likely to turn on and off at the proper time—instead of following the lead of a neighboring gene. In mice, scientists found that a newly inserted gene functioned more reliably with the insulator. It's known as a matrix attachment site—that is, a point on a chromosome that separates an individual gene from its neighbor. The finding will boost progress in genetically engineering cattle and other farm animals for disease resistance, leaner meat, and other traits. *Robert J. Wall, USDA-ARS Gene Evaluation and Mapping Laboratory, Beltsville, Maryland; phone (301) 504-8362.*

Remote Data Gives Environmental Close-Ups

Satellite imagery and low-altitude video from aircraft can now help find, map, and monitor black mangroves along the Gulf Coast. Communities of mangrove shrubs—mostly in remote, inaccessible terrain—protect shorelines and supply wildlife habitat. Now, computer analyses of remote sensing data have yielded the first good baseline information for monitoring the condition of these environmentally important plants. The analyses were done by ARS and the Pan American Coastal Studies Laboratory at the University of Texas. Other ARS computerized maps and data are helping the National Audubon Society and Texas A&M University's Caesar-Kleberg Wildlife Management Institute evaluate habitat for ocelot and Northern Aplomado falcon—both on the federal list of endangered species. *James H. Everitt, USDA-ARS Remote Sensing Research, Weslaco, Texas; phone (210) 969-4824.*

Cornstarch R&D With Illinois Firm

To explore commercial development of food additives made from cornstarch and natural gums from plants such as guar, ARS has entered into a cooperative R&D agreement with Continental Colloids, Inc., of West Chicago, Illinois. Researchers at ARS found that the starch-gum mixtures have many properties required for fat substitutes and food thickeners. A mix of about 95 percent cornstarch and 5 percent gum will be tried as a thickener in dairy products. Natural xanthan and guar gums are already being used as thickeners in puddings, pie fillings, and salad dressings. *George F. Fanta, USDA-ARS Plant Polymer Research, Peoria, Illinois; phone (309) 681-6356.*

The Case of the Disappearing Beachgrass

A newly discovered nematode is among the microscopic culprits in a 20-year mystery—the sporadic withering away of American beachgrass on many sand dunes from Massachusetts to North Carolina. This grass is the primary plant used to build and stabilize dunes that help protect the mid-Atlantic shoreline from storms. Two years ago, ARS and University of Delaware scientists found several species of wormlike nematodes, including one they now know is a new species, feeding on beachgrass roots. It's in the genus *Meloidogne.* Sand-dune experts are using the research findings to work out new ideas for protecting grass and dunes from damage. *Zafar Handoo and Morgan Golden, USDA-ARS Nematology Laboratory, Beltsville, Maryland; phone (301) 504-6666.*

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American beachgrass.

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Upcoming in the October Issue

- Dubbed the Miracle Crop in the 1920's and 1930's, soybeans are still turning into new products and profits for American farmers. In this first of a two-part series, Agriculture Research Service scientists lend a hand in overcoming production problems.

- Let us show you a Demonstration Erosion Control Project in Mississippi that's cleaning up the water, restoring the ecology, and protecting the environment.

- Yesterday's newspaper or last year's telephone directory might turn up in compost pellets rather than the landfill if research on trash recycling at several ARS locations pays off.